Geostationary Operational Environmental Satellite (GOES)

GOES-R Series

Advanced Baseline Imager

Performance and Operational Requirements Document (PORD)

Baseline Version

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To verify the correct version of this document, please contact the GOES R Series Requirements Management Office on 301-286-7898

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1 Scope

1.1

1.1 Identification

This Performance and Operational Requirements Document (PORD) sets forth the performance requirements for the National Oceanic and Atmospheric Administration (NOAA) Advanced Baseline Imager (ABI).

1.2 Mission Review

1.2-1 The ABI is a multi-channel, visible through infrared, passive imaging radiometer used to measure environmental data as part of a 3-axis stabilized, geostationary weather satellite system. The ABI, in conjunction with a sounding instrument, remotely collects data on the Earth's surface (land and water) and atmosphere to aid in the prediction of weather and climate monitoring. The ABI data provides moderate spatial and spectral resolution at high temporal and radiometric resolution to accurately monitor rapidly changing weather.

1.2-2 The ABI objectives are as follows:

- Provide environmental data that will be used by NOAA and other public and private agencies to produce routine meteorological analyses and forecasts.

- Maintain continuity of Geostationary Operational Environmental Satellite (GOES) services to the user agencies.

- Provide environmental data that will be used to expand knowledge of mesoscale and synoptic scale storm development and provide data that may be used to help in forecasting severe weather events.

1.2-3 The ABI instrument, designated as ABI in this document, provides data to the ABI Ground System, designated as ABI-GS in this document, via the spacecraft communication system. The ABI-GS takes the ABI data, spacecraft telemetry data, orbit determination data and other required information and autonomously generates radiometrically calibrated and navigated data for the NOAA users.

The ABI-GS will be procured by the Government but will implement algorithms developed by the ABI contractor to satisfy ABI performance requirements.

The ABI-GS will calibrate and then resample the ABI data to generate the fixed grid. Resampling requires that the raw imagery be adequately sampled to maintain radiometric accuracy after resampling.

1.3

1.3 Document Overview

This document contains all performance requirements for the ABI instrument and Ground Support Equipment (GSE). This document, the General Interface Requirements Document (GIRD), and the ABI Unique Instrument Interface Document (UIID) define all instrument to spacecraft interfaces for the ABI instrument.

1.4

1.4 Terminology

The term "(TBS)", which means "to be specified", means that the contractor will supply the missing information in the course of the contract. These serve as a placeholder for future requirements. The contractor is not liable for compliance with these "placeholder" requirements, as insufficient information is provided on which to base a design.

The term "(TBR)", which means "to be refined/reviewed", means that the requirement is subject to review for appropriateness and subject to revision. The contractor is liable for compliance with the requirement as if the "TBR" notation did not exist. The "TBR" merely provides an indication that the value is more likely to change in a future modification than requirements not accompanied by a "TBR".

1.5 Definitions

1.5-1 Throughout this document, the following definitions apply:

<u>Accuracy:</u> Refers to the error in a measurement, that is the difference between the measurement result and the object to be measured (the measured or true value). It includes both systematic and random errors. Systematic errors must be estimated from an analysis of the experimental conditions and techniques. Random errors can be determined, and reduced, through repeated measurements under identical conditions

<u>Albedo:</u> Refers to the fraction of the solar spectrum taken from the default MODTRAN solar irradiance file, version 4V1R1 (newkur.dat) that is reflected by the Earth at the top of the atmosphere assuming a Lambertian surface.

<u>All requirements/all performance requirements/all operational requirements:</u> Refers to any performance characteristic or requirement in the ABI PORD, ABI UIID, and the GIRD .

<u>CONUS-scanline</u>: Refers to any line of pixels that extends in an EAST-WEST direction across the CONUS area in the fixed grid format of GOES ABI data.

<u>CONUS</u>: Defined as a nadir-viewed rectangle 8.0215 x 4.8129 degrees, 5000 East/West x 3000 North/South kilometers, approximately in the geographic area of 10N-60N latitude and 60W-125W longitude.

<u>CONUS-swath</u>: Refers to any swath used to generate CONUS-scanlines.

<u>Derived Noise Equivalent Delta Radiance (NEDN)</u>: Refers to the NEDN required to meet the Noise Equivalent Delta Temperature (NEDT) specification or Signal-to-Noise Ratio (SNR) specification.

<u>Detector sample or element:</u> Refers to the output of a physical detector after the Analog-to-Digital (A/D) converter and Time Delay and Integration (TDI) processing, if applicable.

<u>Eclipse:</u> Defined as when the solar disk is completely occulted by the Earth or Moon, as viewed from the GOES satellite.

<u>Fixed Grid Format:</u> Refers to the idealized georeferenced positions for pixel locations. The fixed grid has the following characteristics:

- The fixed grid is rectified to a GRS80 geoid viewed from the idealized geostationary position.
- The pixels have the same angular separation for East/West and North/South.
- From the viewpoint of a right-hand coordinate system of the idealized geostationary satellite with its x-axis in the direction of the velocity and the z-axis pointed at nadir, the North/South angle is determined by a rotation about the x-axis and the East/West angle is determined by a rotation about the rotated y-axis.
- For the 0.64 micron channel the angular separation is 14 microradians.
- For the 0.47, 0.86, and 1.61 micron channels the angular separation is 28 microradians.
- For all other channels, the angular separation is 56 microradians.
- The center of the 14 microradian grid is offset by 7 microradians in both directions from the center of the 28 microradian grid such that four 14

microradian pixels fill the same area as a single 28 microradian pixel.

- The center of the 28 microradian grid is offset by 14 microradians in both directions from the center of the 56 microradian grid such that four 28 microradian pixels fill the same area as a single 56 microradian pixel.
- The ideal sub-satellite point is at the corner of a pixel on the 14, 28, and 56 microradian grids.
- Pixels within an angular radius of 8.66 degrees from the ideal geosynchronous satellite use the ideal satellite as the viewpoint.
- Pixels off the limb of the earth as observed from the actual satellite position use the actual satellite position as the viewpoint.
- Pixels between 8.66 degrees as observed by the ideal geosynchronous satellite position and pixels on the earth limb as observed from the actual satellite position use a viewpoint that is linearly interpolated between the ideal position of the satellite and the actual position of the satellite.

Full Disk: Defined as a 17.76 degree diameter circle centered at nadir, where 0.36 degree is added to the nominal Earth diameter of 17.4 degrees for non ideal orbital characteristics and anticipated uncompensated image motion.

Fully Functional Configuration: Being able to perform the following functions: scene radiance measurement; radiometric calibration; star sensing; on-orbit monitoring of calibration sources and instrument response changes; acquisition of sensor health and status data; generation of sensor, calibration, monitoring, health and status data streams; and reception and execution of command and control data.

Image: Refers to a full disk, CONUS, or mesoscale image in the fixed grid.

Image Navigation: Refers to the determination of the location of each image pixel relative to a fixed reference, such as fixed-grid angle coordinates.

Image Registration: Refers to maintaining the spatial relationship between pixels within images, between images, and between channels.

Launch: The period of time between lift off and the separation of the GOES-R series satellite from the launch vehicle.

Mesoscale Region: Defined as the equivalent of a 1.6043 x 1.6043 degree, 1000 x

1000 kilometer nadir-viewed area.

Navigation Error: Refers to the angular error of locations in the resampled fixed-grid image.

Pixel: Applies to data samples after resampling during the ground processing.

Polarization Sensitivity: Defined as the ratio of the difference between maximum and minimum output to the sum of the maximum and minimum output obtained when the plane of incoming 100% linearly polarized radiation is rotated through 180 degrees.

Precision: Refers to the standard deviation of a statistically meaningful number of samples of a measurement.

Scanline: Refers to any line of pixels that extends in an East-West direction across the Earth or space in the fixed grid format of GOES ABI data.

Swath: Refers to any set of detector samples that are collected during a continuous scan of the detectors over the scene.

Transfer Orbit: The sequence of events that transpires to establish the GOES R series satellite on-station after the GOES R series satellite has separated from the launch vehicle.

Unit: A functional subdivision of a subsystem and generally a self-contained combination of items performing a function necessary for the subsystem's operation. Examples are electronics unit and sensor unit.

1.6

1.6 Requirement Applicability

The requirements in this ABI PORD pertain to the ABI 'system', which may include scanner, optics, detectors, signal processing electronics and software, and ground processing. The ABI contractor is not responsible for the whole ABI-GS, but certain specifications may require some level of ground processing after collection but before data distribution, i.e. decompression, re-sampling, and calibration.

All requirements apply over the entire life of the ABI. Data performance requirements, such as Modulation Transfer Function (MTF) and Image Navigation and Registration (INR), apply to data after all ground processing, except as indicated.

2 Applicable Documents

2-1 The following form a part of this specification to the extent specified herein.

A New Distortion Measure for Video Coding Blocking Artifacts. Wu, H. R., Proceedings from the 1996 International Conference on Communication Technology. Volume 2, May 5-7, 1996, Beijing, China. pp 658-651.

CCSDS Recommendation for Space Data System Standards, Lossless Data Compression, CCSDS 121.0-B-1, May 1997.

Structural Design and Test Factors of Safety for Spaceflight Hardware, NASA, Document Number NASA-STD-5001, June 21, 1996

General Specification for Assemblies, Moving Mechanical, for Space and Launch Vehicles, Document Number MIL-A-83577B, February 1, 1988

Space Mechanisms Handbook, Document Number NASA TP-1999-206988

General Environmental Verification Specification for STS and ELV Payloads, Subsystems and Components, Document Number GSFC GEVS-SE, June1, 1996

Eastern and Western Range Policies and Procedures, Document Number EWR-127-1, Oct. 23, 2000

Standard General Requirements for Safe Design and Operation of Pressurized Missile and Space Systems, Document Number MIL-STD-1522, Sept. 4, 1992

Radiance Upwelling, 417-R-RPT-0064 dated May 3, 2004

3 Sensor Requirements

3.1 Sensor Definition

3.1.1 ABI Modes

ABIPORD31	3.1.1-1	The ABI **shall** execute commands to individually enable and disable each autonomous function.
ABIPORD32	3.1.1-2	The ABI **shall** initiate all commanded mode transitions in no more than 20 seconds after receipt of command.
ABIPORD350	3.1.1-3	The ABI **shall** make limits and triggers of autonomous functions changeable by command.
ABIPORD466	3.1.1-4	The ABI **shall** transition from its current mode to any other mode without causing permanent damage to itself.
ABIPORD467	3.1.1-5	The ABI **shall** indicate the mode of the instrument in housekeeping telemetry.
ABIPORD471	3.1.1-6	The ABI **shall** provide command and housekeeping telemetry functions in all powered modes.

3.1.1.1 Safe Mode

ABIPORD469	3.1.1.1-1	The ABI **shal**l implement a Safe Mode.
ABIPORD470	3.1.1.1-2	The ABI **shall** be in a thermally and optically safe configuration for an indefinite period of time while in Safe Mode.
ABIPORD473	3.1.1.1-3	The ABI **shall** enter Safe Mode upon detection of internal faults capable of causing permanent damage to the instrument.

3.1.1.2 Normal Operational Mode

ABIPORD46	3.1.1.2-1	The ABI **shall** be in a fully functional configuration while in Normal Operational Mode.

3.1.1.3 Instrument Diagnostic Mode

ABIPORD53	3.1.1.3-1	The ABI **shall** implement an Instrument Diagnostic Mode.
ABIPORD54	3.1.1.3-2	The ABI **shall** be in a fully functional configuration while in Instrument Diagnostic Mode.
ABIPORD55	3.1.1.3-3	The ABI **shall** by command send selected channels while in Instrument Diagnostic Mode.
ABIPORD474	3.1.1.3-4	The ABI **shall** by command send the individual measurement in those cases where TDI data is digitally processed off the focal plane while in Instrument Diagnostic Mode.
ABIPORD475	3.1.1.3-5	The ABI **shall** by command send data from all detectors while in Instrument Diagnostic Mode.
ABIPORD476	3.1.1.3-6	The ABI **shall** by command send the same data both compressed and

uncompressed if the data is capable of being compressed while in Instrument Diagnostic Mode.

ABIPORD477 3.1.1.3-7 The ABI **shall** by command send all bits from the A to D converter while in Instrument Diagnostic Mode.

ABIPORD478 3.1.1.3-8 The ABI **shall** by command perform electronic in-flight calibration while in Instrument Diagnostic Mode.

ABIPORD537 3.1.1.3-9 The ABI **shall** by command send dwell data (increased samples per second of a particular telemetry measurand) while in Diagnostic Mode.

3.1.1.4 Outgas Mode

ABIPORD57 3.1.1.4-1 The ABI **shall** implement an Outgas Mode.

ABIPORD59 3.1.1.4-2 The ABI **shall** sublimate and evaporate contaminants from ABI hardware to prevent contamination from jeopardizing ABI performance while in Outgas Mode.

3.1.2 On-Orbit Operations

3.1.2.1 Zones of Reduced Data Quality

3.1.2.1.1 Operational Zone

ABIPORD82 3.1.2.1.1-1 The ABI **shall** meet all of its performance requirements for all pixels in channels greater than 3 microns whose distance from the center of the uneclipsed portion of the sun is greater than 7.5 degrees.

3.1.2.1.1-2 The ABI **shall** meet all of its performance requirements for all pixels in channels less than 3 microns when the distance from the center of the sun to any part of the earth is greater than the limits in the Operational Zones Table.

Operational Zones Table

Channel	Outer Limit
Low light	10°
All other reflective	7.5°

3.1.2.1.2 Restricted Zone

ABIPORD84 3.1.2.1.2-1 For all pixels in channels greater than 3 microns whose distance from the center of the uneclipsed portion of the sun is between the inner and outer limits shown in the Restricted Zones Table, the ABI **shall** meet all requirements, except for a factor of two degradation of the SNR and NEDT requirements stated in requirement number ABIPORD148, a factor of two degradation of the absolute accuracy requirement stated in ABIPORD219, and a navigation relaxation as described in ABIPORD202.

Restricted Zones Table

Channel	Inner Limit	Outer Limit
3.9 micrometers	5°	7.5°
All others	3°	7.5°

3.1.2.2 Scanning Across the Sun

ABIPORD87 3.1.2.2-1 The ABI **shall** be able to scan across the sun at its normal scan rate two times within 30 seconds or less without interrupting normal imaging operations or sustaining damage.

3.1.2.3 Eclipse

ABIPORD89 3.1.2.3-1 The ABI **shall** be capable of continuous operation through eclipse periods.

ABIPORD90 3.1.2.3-2 During eclipse periods, for all channels with wavelengths greater than 3 microns, the ABI **shall** meet all requirements, except as noted in requirement number ABIPORD202.

3.1.2.4 Operations After Maneuvers

3.1.2.4.1 Yaw Flip

ABIPORD93 3.1.2.4.1-1 The ABI **shall** meet the channel definitions, NEDT, dynamic range and Radiometric Accuracy and Precision sections within 1 hour after the spacecraft interface has returned to being within specification following a yaw flip.

ABIPORD94 3.1.2.4.1-2 The ABI **shall** meet INR requirements within 1 day after the spacecraft attitude has returned to being within specification following a yaw flip.

3.1.2.4.2 Stationkeeping

ABIPORD96 3.1.2.4.2-1 The ABI **shall** meet all radiometric, coverage and INR requirements within 60 minutes after the spacecraft interface has returned to being within specification following spacecraft stationkeeping maneuvers.

3.1.2.4.3 Post Storage Activation

ABIPORD98 3.1.2.4.3-1 The ABI **shall** meet all requirements within 5 days of ABI turn on after post storage activation for an ABI with passively cooled detectors and 3 days for an ABI with actively cooled detectors.

3.1.2.5 Detector Operating Temperatures

ABIPORD100 3.1.2.5-1 The ABI detector operation temperatures **shall** be selectable by command.

ABIPORD101 3.1.2.5-2 The ABI detector control temperature **shall** be in 1K increments or smaller.

ABIPORD479 3.1.2.5-3 The ABI detector control temperature **shall** be at least +10K/-5K of the nominal operational temperature.

ABIPORD102 3.1.2.5-4 The precision on the control temperatures of the ABI detector **shall** be less than +/- 0.5 K.

3.2 Sensor Characteristics

3.2.1 Coverage

3.2.1.1 Scan Modes

ABIPORD107 3.2.1.1-1 Routine operations, such as uploading commands and data to the ABI, **shall** not interfere with data collection in any scan mode.

ABIPORD320 3.2.1.1-2 The ABI **shall** be capable of interrupting current operations by command and starting the acquisition of a new image, after an image coordinate upload, within 30 seconds.

3.2.1.1.1 Scan Mode 3

ABIPORD109 3.2.1.1.1-1 The ABI **shall** acquire concurrently:

- Full Disks at 15 minute intervals,
- CONUS images at 5 minute intervals, any of which may be extracted from the full disk images if the timing is correct,
- A Mesoscale image at 30 second intervals,
- Any other observations required to meet radiometric and INR requirements.

3.2.1.1.2 Scan Mode 4

ABIPORD111 3.2.1.1.2-1 The ABI **shall** acquire concurrently:

- Full Disks at 5 minute intervals,
- Any other observations required to meet radiometric and INR requirements.

3.2.1.1.3 Full Disk

ABIPORD113 3.2.1.1.3-1 In Mode 3, an image of the Full Disk **shall** be acquired with all corresponding pixels in consecutive frames spaced at an average time of 15 minutes with a peak deviation of no more than ± 30 seconds.

ABIPORD114 3.2.1.1.3-2 In Mode 4, an image of the Full Disk **shall** be acquired with all corresponding pixels in consecutive frames spaced at an average time of 5 minutes with a peak deviation of no more than ± 5 seconds.

3.2.1.1.4 CONUS

ABIPORD116 3.2.1.1.4-1 In Mode 3, an image of the CONUS area **shall** be acquired with all corresponding pixels in consecutive frames spaced at an average time of 5 minutes with peak deviation of no more than +/- 30 seconds. The ABI design may assume that the spacecraft x axis is parallel to the Earth's equator within the accuracy as stated in the GIRD.

3.2.1.1.5 Mesoscale

ABIPORD118 3.2.1.1.5-1 In Mode 3, an image of a Mesoscale region viewed anywhere on the disk **shall** be acquired with all corresponding pixels in consecutive frames spaced at an average time of no more than 30 seconds apart with a peak deviation of +/- 5 seconds.

3.2.1.2 Flexible and Efficient Scan Pattern

ABIPORD120 3.2.1.2-1 The ABI **shall** be designed such that the scan patterns are programmable on-orbit.

ABIPORD121 3.2.1.2-2 The ABI **shall** accept fixed grid coordinates for all Scan Modes.

ABIPORD123 3.2.1.2-3 In addition to Full Disk scans, the ABI **shall** have the capability to program CONUS scans.

ABIPORD124 3.2.1.2-4 In addition to Full Disk scans, the ABI **shall** have the capability to program Mesoscale scans anywhere within the Field of Regard (FOR).

ABIPORD125 3.2.1.2-5 The ABI **shall** autonomously adjust the Scan Pattern to avoid scanning within a ground definable angle from the center of the sun.

ABIPORD126 3.2.1.2-6 If star sensing is used, the ABI **shall** autonomously onboard compute the position of stars and adjust the scan pattern to acquire them (with any adjusted scan pattern still meeting all other requirements in this document).

ABIPORD127 3.2.1.2-7 The scan pattern **shall** be definable by ground modifiable parameters such that full disk, CONUS, and mesoscale images, other image regions and sizes, space looks, IR calibration, and star sensing are performed at any user-defined intervals that are consistent with the scan rates and slew rates used in predefined scan modes. These data items will be uploaded during earlier operations and activated with a single command.

3.2.1.3 Field of Regard

ABIPORD129 3.2.1.3-1 The ABI's unvignetted Field of Regard (FOR) **shall** include a circle of at least 20 degrees in diameter with its center at the sub-satellite point and accounting for alignment errors as described in the GIRD.

3.2.1.4 Simultaneity

ABIPORD132 3.2.1.4-1 Corresponding pixels in all spectral channels **shall** be calculated from detector samples collected within 5 seconds of each other.

ABIPORD133 3.2.1.4-2 All adjacent North/South pixels **shall** be calculated from detector samples collected within 30 seconds of each other.

ABIPORD134 3.2.1.4-3 At least 99.5 % of adjacent East/West pixels **shall** be calculated from detector samples collected within 15 seconds of each other.

3.2.1.5 Data Timeliness

ABIPORD136 3.2.1.5-1 The ABI **shall** contribute to the total data latency no more than: 50 seconds for a CONUS calibrated, navigated image; 20 seconds for a Mesoscale calibrated navigated image; and 350 seconds for a Full Disk calibrated, navigated image.

Data latency is measured from the time the instrument acquires all samples for a scene to the time the image is available for dissemination on the ground. The ABI contribution to data latency includes delay of delivery of data to the spacecraft and delay due to ground algorithm processing (i.e., resampling and INR).

3.2.1.6 Data Acquisition Direction

ABIPORD140 3.2.1.6-1 The ABI **shall** acquire data in a predominantly East/West and/or West/East direction.

ABIPORD141 3.2.1.6-2 Image acquisition **shall** begin with the northern most coordinates and proceed south.

3.2.1.7 Data Collection Overlap

ABIPORD143 3.2.1.7-1 The ABI **shall** generate each pixel from detector samples contained in a single swath.

3.2.2 Channel Definitions, NEDT, Dynamic Range

3.2.2.1 Baseline

ABIPORD147 3.2.2.1-1 The ABI **shall** collect imagery in the following 16 channels designated by their center wavelength in microns: 0.47, 0.64, 0.86, 1.38, 1.61, 2.26, 3.9, 6.185, 6.95, 7.34, 8.5, 9.61, 10.35, 11.2, 12.3, 13.3.

ABIPORD148 3.2.2.1-2 The ABI **shall** meet the SNR, and NEDT listed in the following ABI Radiometric Precision Table.

ABI Radiometric Precision Table

Center Wavelength Microns	NEDT @300K +/- 1K (K)	NEDT @240K +/- .5K (K)	SNR at 100% albedo
0.47	-	-	SNR=300:1
0.64	-	-	SNR=300:1
0.86	-	-	SNR=300:1
1.38	-	-	SNR=300:1
1.61	-	-	SNR=300:1
2.26	-	-	SNR=300:1
3.9	0.10	1.4	
6.185	0.10	0.4	
6.95	0.10	0.37	
7.34	0.10	0.32	
8.5	0.10	0.27	
9.61	0.10	0.22	
10.35	0.10	0.21	
11.2	0.10	0.19	
12.3	0.10	0.18	
13.3	0.30	0.48	

ABIPORD149 3.2.2.1-3 The ABI **shall** meet the dynamic range listed in the following ABI Dynamic Range Table for detector samples.

ABI Dynamic Range Table

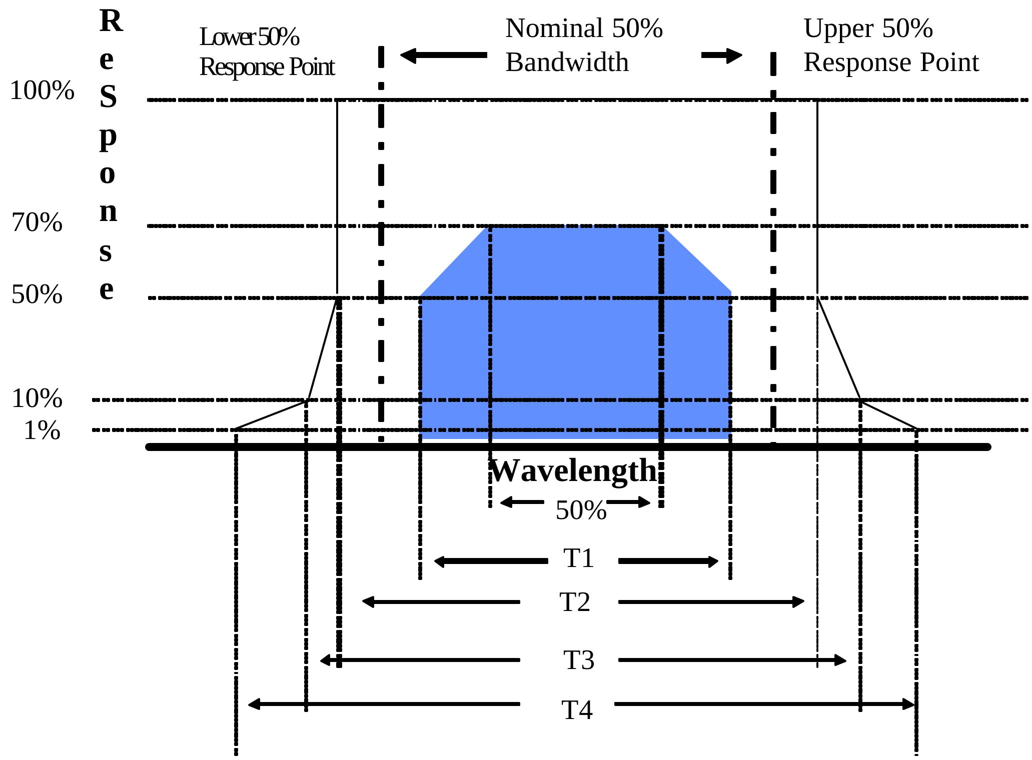
Center Wavelength Microns	Scene T_{min} (K)	Scene T_{max} (K)	N_{max} ($mW/m^2/sr/cm^{-1}$)
0.47	N/A	-	14.4
0.64	N/A	-	21.1 1.05
0.86	N/A	-	22.8
1.38	N/A	-	21.7
1.61	N/A	-	20.0
2.26	N/A	-	12.1
3.9	4	400	
6.185	4	300	
6.95	4	300	
7.34	4	320	
8.5	4	330	
9.61	4	300	
10.35	4	330	
11.2	4	330	
12.3	4	330	
13.3	4	305	

3.2.2.2 System Spectral Response

3.2.2.2.1 Spectral Response Envelope

ABIPORD154 3.2.2.2.1-1 The ABI system spectral response **shall** conform to the envelope per the Spectral Response Figure and Table.

Spectral Response Figure



Spectral Response Table

Nominal Center Wavelength (µm)	T1 (µm)	T2 (µm)	T3 (µm)	T4 (µm)	Nominal 50% Bandwidth
Baseline Channels					
0.47	0.02	0.054	0.054	0.07	0.04
0.64	0.08	0.12	0.135	0.175	0.10
0.86	0.02	0.054	0.054	0.07	0.04
1.38	0.02	0.04	0.0405	0.0525	0.03
1.61	0.04	0.08	0.081	0.105	0.06
2.26	0.03	0.0675	0.0675	0.0875	0.05
3.9	0.1	0.27	0.27	0.35	0.20
6.185	0.77	0.89	1.1205	1.4525	0.83
6.95	0.34	0.46	0.54	0.7	0.40
7.34	0.16	0.24	0.27	0.35	0.20
8.5	0.34	0.46	0.54	0.7	0.40
9.61	0.32	0.44	0.513	0.665	0.38
10.35	0.3	0.675	0.675	0.875	0.50
11.2	0.6	1.00	1.08	1.4	0.80
12.3	0.8	1.2	1.35	1.75	1.0
13.3	0.48	0.72	0.81	1.05	0.6

ABIPORD155 3.2.2.2.1-2 When viewing the four government-supplied simulated upwelling radiance data sets in 417-R-RPT-0064, the brightness temperature error due to the uncertainty in the spectral response between the 1% response points **shall** be less than 1K for all channels with center wavelength greater than 3 microns.

3.2.2.2.2 Within Channel Spectral Response Uniformity

ABIPORD160 3.2.2.2.2-1 When viewing the simulated upwelling radiance data sets in 417-R-RPT-0064 and when viewing the default solar irradiance spectrum from MODTRAN version 4V1R1 (newkur.dat) with the assumption that clouds have Lambertian reflectance with an albedo not less than 50%, the variation in radiance measured between the 1% response points in each spectral channel, due to spectral differences over the focal plane, **shall** be less than the derived NEDN for all channels.

3.2.2.2.3 Out-of-Band Response

ABIPORD164 3.2.2.2.3-1 The out-of-band response is defined in the equation as one minus the integrated response between the 1% response points divided by the integrated response from 0.3 microns to 20 microns. Out-of-band response **shall** be less than 0.25% of the signal for the 1.38 micron channel and 1% of the total signal for all other channels when viewing either a 300 K blackbody (for channel wavelengths greater than 3 microns) or a 100% albedo scene above the atmosphere assuming no attenuation.

Out-of-Band Response Equation

$$\text{(Equation 1)}\quad 1-\left(\frac{\int_{-l_{1\%}}^{+l_{1\%}} N(l)R(l)dl}{\int_{l_{0.3\,mm}}^{l_{20\,mm}} N(l)R(l)dl} \right) \leq 0.01 \quad \text{where}$$

$N(l) = 300$ K blackbody or 100% albedo and
$R(l)$ is the channel relative spectral response

3.2.2.3 Low Light Visible Channel

ABIPORD166 3.2.2.3-1 The ABI **shall** include a low light level (5% albedo) visible (0.64 microns) imaging capability at 50:1 SNR with performance equivalent to the 0.64 microns visible channel except as noted in requirements ABIPORD 82 and 84.

3.2.3 Spatial Resolution and Sampling

3.2.3.1 System Modulation Transfer Function

ABIPORD171 3.2.3.1-1 The ABI spatial resolution is defined by the sensor system sinusoidal MTF. The following MTF values (exact specification is in cycles/rad) are consistent with 0.5 kilometer resolution in the 0.64 micron channel, 1.0 kilometer resolution in the 0.47 micron channel, 1.0 kilometer resolution in the 0.86 micron channel, 1.0 kilometer resolution in the 1.61 micron channel, and 2.0 kilometer resolution in all other channels. The spatial frequencies, when referenced to kilometers, are measured at nadir. The ABI system MTF **shall** meet the requirements in the following tables over the Full Disk image area, in both East/West and North/South directions, after any ground processing, in the presence of jitter, when averaged over all resampling phases of the detector sample grid to pixel grid, and after any lossy compression/decompression.

ABI MTF Emissive Channel Requirements Table

All channels greater than 3 microns

Spatial Period	Spatial Frequency	System MTF
km/cyc	cyc/rad	
16.0	2250	0.84
8.0	4500	0.62

5.333	6750	0.39
4.0	9000	0.22

ABI MTF Reflective Channel Requirements Table

0.64 micron channel			0.47, 0.86, 1.61 micron channels			1.38 and 2.26 channels		
Spatial Period	Spatial Frequency	System MTF	Spatial Period	Spatial Frequency	System MTF	Spatial Period	Spatial Frequency	System MTF
km/ cyc	cyc/rad		km/ cyc	cyc/rad		km/ cyc	cyc/rad	
4.0	9000	0.90	8.0	4500	0.90	16.0	2250	0.90
2.0	18000	0.73	4.0	9000	0.73	8.0	4500	0.73
1.333	27000	0.53	2.666	13500	0.53	5.333	6750	0.53
1.0	36000	0.32	2.0	18000	0.32	4.0	9000	0.32

3.2.3.2 Spatial Response Uniformity

ABIPORD178 3.2.3.2-1 Effects of co-registration and jitter may be ignored for the purposes of evaluating these requirements (ABIPORD 178 through 182).

The normalized radiance difference due to spatial response differences between corresponding pixels in any two spectral channels with a center wavelength greater than 3 microns located X (continuous variable) microradians from the edge of a 1000 by 1000 microradian or larger target with radiance equal or greater than 300 K surrounded by a large region of radiance equal to or less than 240 K **shall** agree to within 4 % of the step radiance difference for an rms over the sampling-to-edge phasing and the channel-to-channel relative phasing. The calculation of this normalized difference is expressed in equation form below.

Here the overbar represents an average over multiple samples located well away from the edge. This normalized radiance difference due to spatial response differences applies in all four directions, i.e. left of, right of, above, and below the target box. The values of X include all distances between +84 microradians and -84 microradians.

$$L_{norm} = \left(L - \overline{L_{240}}\right) \Big/ \left(\overline{L_{300}} - \overline{L_{240}}\right)$$

$$S_{norm} = \left(S - \overline{S_{240}}\right) \Big/ \left(\overline{S_{300}} - \overline{S_{240}}\right)$$

$$Diff = L_{norm} - S_{norm}$$

ABIPORD179 3.2.3.2-2 Any efforts to blur or enhance channel resolution to match that of other emissive (greater than 3 microns) channels **shall** be performed in ground system software, not within the ABI instrument.

ABIPORD180 3.2.3.2-3 The reflectance difference due to spatial response differences between corresponding pixels in any two spectral channels with a center wavelength of 0.47, 0.86 and 1.61 microns located X (continuous variable) microradians from an edge of a 1000 by 1000 microradian or larger target with radiance equal to N_{max} (see requirement ABIPORD149) surrounded by a large region of radiance equal to or less than 5% N_{max} **shall** be less than 4% of the step function for an rms over the sampling-to-edge phasing and the channel-to-channel relative phasing.

ABIPORD181 3.2.3.2-4 The reflectance difference due to spatial response differences between corresponding pixels in the two spectral channels with center wavelengths of 1.38 and 2.26 microns located X (continuous variable) microradians from an edge of a 1000 by 1000 microradian or larger target with radiance equal to N_{max} (see requirement ABIPORD 149) surrounded by a large region of radiance equal to or less than 5% N_{max} **shall** be less than 4% of the step function for an Root Mean Square (RMS) over the sampling-to-edge phasing and the channel-to-channel relative phasing. This reflectance difference due to spatial response differences applies in all four directions, i.e. left of, right of, above, and below the target box. The values of X include all distances between +84 microradians and -84 microradians.

ABIPORD182 3.2.3.2-5 Any efforts to blur or enhance channel resolution to match that of other reflective (less than 3 microns) channels **shall** be performed in ground system software, not within the ABI.

3.2.3.3 Ringing from a Sharp Edge

ABIPORD185 3.2.3.3-1 For both the North/South and East/West edges, the ABI **shall** not overshoot the top of an edge or undershoot the bottom of edge by more than 2% of the height of the edge where:

- the height and the overshoot/undershoot are measured in radiance units.
- the edge delineates a 10% albedo region from a 90% albedo region for channels less than 3 microns.
- the edge delineates a 240K region from a 300K region for channels greater than 3 microns.
- the overshoot is averaged over all resampling phases of the detector sample grid to pixel grid and edge position to detector sample grid.

3.2.4 Image Navigation and Registration

3.2.4.1 Star Sensing

ABIPORD194 3.2.4.1-1 If star sensing is employed onboard, the ABI **shall** have an on-board star catalog which is loadable and modifiable from the ground.

ABIPORD195 3.2.4.1-2 If star sensing is employed onboard, the ABI **shall** be capable of being commanded to acquire an ABI-GS list of target stars that will be within the nominal FOR for the next 26 hours

3.2.4.2 INR Performance Requirements

3.2.4.2-1 All INR requirements listed herein refer to location error of the ABI fixed-grid pixels; i.e., the requirements apply to the end-to-end system, taking all instrument, spacecraft, and ground processing effects into account. Unless otherwise specified, all INR requirements in this document are specified as North/South and East/West angles, in microradians, 3-sigma, and refer to all hours of operation.

In addition, for the purposes of this section, 3-sigma is defined as the average +/- 3 times the square root of the variance for a population of 100 consecutive observations.

3.2.4.2.1 Navigation

ABIPORD201 3.2.4.2.1-1 The ABI navigation error **shall** not exceed +/- 21 microradians except during eclipse periods.

ABIPORD202 3.2.4.2.1-2 For up to a four hour period that includes a total or partial eclipse of the sun, the ABI navigation requirement in ABIPORD201 **shall** be relaxed to not exceed +/- 32 microradians. The phasing of the four hour relaxation relative to the eclipse may be design-specific and is TBS.

3.2.4.2.2 Frame-to-Frame Registration

ABIPORD204 3.2.4.2.2-1 Frame-to-frame registration error **shall** not exceed ±16 microradians for the 0.47, 0.64, 0.86, and 1.61 micron channels. Frame-to-frame registration error is the difference in navigation error for any given pixel in two consecutive images within the same channel.

ABIPORD205 3.2.4.2.2-2 Frame-to-frame registration error **shall** not exceed ±21 microradians for the 1.38, 2.26, 3.9, 6.185, 6.95, 7.34, 8.5, 9.61, 10.35, 11.2, 12.3, and 13.3 micron channels.

3.2.4.2.3 Within Frame Registration

ABIPORD207 3.2.4.2.3-1 Within an image in the same channel, any two pixels **shall** be separated by the known fixed distance to within +/- 21 microradians.

3.2.4.2.4 Swath-to-Swath Registration

ABIPORD209 3.2.4.2.4-1 Swath-to-swath registration error **shall** not exceed +/- 5.2 microradians, where swath-to-swath registration error is the relative location error of adjacent pixels across a swath boundary within the same channel.

3.2.4.2.5 Channel-to-Channel Registration

ABIPORD211 3.2.4.2.5-1 Channel-to-channel registration error, or co-registration, is the difference in navigation errors between spectral channels for any given pixel in the same frame. The channel-to-channel registration requirements depend on the fixed-grid resolutions of the channels. Co-registration between channels having different resolutions is defined by centroiding a square grid of the finer pixels to determine a “mean” pixel equal in extent to the coarser pixel.

Co-registration errors between any two ABI spectral channels **shall** not exceed the values shown in the Channel-to-Channel Registration table.

Channel-to-Channel Registration Table

	2-km	**1-km**	**0.5-km**
2-km	6.3 microradian	6.3 microradian	6.3 microradian
1-km	--	5.2 microradian	5.2 microradian

3.2.5 Radiometric Accuracy and Precision

3.2.5.1 IR Channel Calibration and Accuracy for Wavelengths Greater than 3 Microns

3.2.5.1.1 Full Aperture Calibration

ABIPORD217 3.2.5.1.1-1 The ABI **shall** have full system, end-to-end, and full aperture on-board calibration for the IR channels with wavelengths greater than 3 microns.

3.2.5.1.2 Absolute Accuracy

ABIPORD219 3.2.5.1.2-1 The ABI data **shall** be calibrated to an absolute accuracy of +/- 1 K at a 300 K reference temperature.

3.2.5.2 Repeatability

3.2.5.2.1 Pixel-to-Pixel

ABIPORD227 3.2.5.2.1-1 For all channels, while viewing a stable, uniform calibration source over expected geostationary environmental conditions and calibration frequency, the ABI **shall** have a pixel-to-pixel repeatability less than the derived NEDN.

Channels with wavelengths less than 3 microns will be characterized as if viewing a 100% albedo calibration source. Channels with wavelengths greater than 3 microns will be characterized as if viewing a 300 K temperature calibration source.

The pixel-to-pixel repeatability is calculated as follows: for each 3 row by 10 column subset of the image the row average is calculated for each row, the RMS of the row averages is then calculated and must be less than the derived NEDN. This value is then averaged N_{image} times where N_{image} is the number of samples required to state at the 90% confidence level that the requirement has been met for all possible locations on the full disk.

Pixel-to-Pixel Equation

$$\text{Derived NEDN} > \frac{1}{\mathrm{N_{image}}} \sum_{j=0}^{N_{image}-1} \sqrt{\tfrac{1}{3}\sum_{i=0}^{2}\left(\overline{R_i} - \overline{R}\right)^2}$$

where

$\overline{R} = \frac{1}{30}\sum_{i=0}^{2}\sum_{j=0}^{9} P_{i,j}$ is the mean for 30 pixels.

$\overline{R}_i = \frac{1}{10}\sum_{j=0}^{9} P_{i,j}$ is the row mean for row i.

$P_{i,j}$ is the resampled pixel value for row i, column j

This equation applies to be met for all possible locations on the full disk.

3.2.5.2.2 Swath-to-Swath

ABIPORD229 3.2.5.2.2-1 For each channel with a wavelength greater than 3 microns, while viewing a stable, uniform 300 K temperature calibration source over expected geostationary environmental conditions and calibration frequency , the difference in calibrated pixel radiance between swath boundaries in a resampled image **shall** be less than the derived NEDN. The swath-to-swath repeatability is evaluated by computing the RMS of the difference of neighboring row means at swath boundaries for CONUS-wide images. NBoundaries is the number of boundaries required to state at the 90% confidence level that the requirement has been met. In the resampled image, a boundary is where neighboring North/South pixels come from different swath scans.

Swath-to-Swath Equation

$$\text{Derived NEDN} > \sqrt{\frac{1}{NBoundaries} \sum_{i=0}^{NBoundaries-1} (\overline{R}_{North} - \overline{R}_{South})^2}$$

where

$\overline{R} = \frac{1}{M}\sum_{i=0}^{M-1} P_{0,i}$ is the mean of a one pixel high row of M pixels long

3.2.5.2.3 Channel-to-Channel

ABIPORD231 3.2.5.2.3-1 For each channel with a wavelength greater than 3 microns, while viewing a stable, uniform 300 K temperature calibration source over expected geostationary environmental conditions and calibration frequency, the ABI **shall** have a channel-to-channel repeatability less than 0.2 Kelvin. The channel-to-channel repeatability is evaluated by computing the RMS of CONUS image mean differences between each channel pair, over a series of NImages. NImages is the number of images required to state at the 90% confidence level that the requirement has been met.

Channel-to-Channel Equation

$$0.2K > \sqrt{\frac{1}{N\,\mathrm{Im}\,ages} \sum_{r=0}^{N\,\mathrm{Im}\,ages-1} (\bar{T}_{r,c1} - \bar{T}_{r,c2})^2}$$

where

$c1, c2 =$ Channel pair with wavelengths greater than 3 microns

$\bar{T} = \frac{1}{NM} \sum_{i,j=0}^{N-1,M-1} T_{i,j}$ is the mean of a CONUS size image

3.2.5.2.4 Image-to-Image

ABIPORD233 3.2.5.2.4-1 For each channel with a wavelength greater than 3 microns, while viewing a stable, uniform 300 K temperature calibration source over expected geostationary environmental conditions and calibration frequency, the ABI **shall** have an image-to-image repeatability of less than 0.2 Kelvin. The image-to-image repeatability is evaluated by computing the RMS of consecutive CONUS image differences over a series of NImages for each channel. NImages is the number of images required to state at the 90% confidence level that the requirement has been met.

Image-to-Image Equation

$$0.2K > \sqrt{\frac{1}{\mathrm{NImages\ -1}} \sum_{r=0}^{N\,\mathrm{Im}\,ages-2} (\bar{I}_{r+1} - \bar{I}_r)^2}$$

where

$\bar{I} = \frac{1}{NM} \sum_{i,j=0}^{N-1,M-1} P_{i,j}$ is the mean of a CONUS size image

3.2.5.2.5 Blackbody Calibration-to-Calibration

ABIPORD235 3.2.5.2.5-1 For each channel with a wavelength greater than 3 microns, while viewing a stable, uniform 300 K temperature calibration source over expected geostationary environmental conditions and calibration frequency, the ABI **shall** have a calibration-to-calibration repeatability of less than 0.2 Kelvin. The calibration-to-calibration-repeatability is evaluated by computing the RMS of consecutive CONUS image mean differences with a blackbody calibration event between the images. Ncals is the number of image pairs required to state at the 90% confidence level that the requirement has been met.

The calculation is done in radiance units and converted to temperature with a reference temperature of 300 K in the final step.

Blackbody Calibration-to-Calibration Equation

$$0.2K > \sqrt{\frac{1}{NCals}\sum_{r=0}^{NCals-1}(\bar{I}_{before} - \bar{I}_{after})^2}$$

where

$$\bar{I} = \frac{1}{NM}\sum_{i,j=0}^{N-1,M-1} P_{i,j}$$ is the mean of a CONUS size image

3.2.5.3 Coherent Noise

ABIPORD238 3.2.5.3-1 For all channels, while viewing a stable, uniform calibration source over expected geostationary environmental conditions and calibration frequency, the ABI shall have no spatial coherent noise spectral component exceedances. The spatial coherent noise is defined as the 2-D Fourier transform of the pixels of a full disk sized region including all calibration and sampling. An exceedance is defined as any spatial frequency whose magnitude is greater than six times the RMS value of the 100 bin region centered on the bin of interest.

Note: The width of bin is defined by the fixed grid spacing.

Channels with wavelengths less than 3 microns will be characterized as if viewing a 100% albedo calibration source. Channels with wavelengths greater than 3 microns will be characterized as if viewing a 300 K temperature calibration source.

3.2.5.4 Calibration of Channels Less Than 3 Microns

3.2.5.4.1 On-Board Calibration

ABIPORD246 3.2.5.4.1-1 The ABI **shall** have an on-board calibration capability for the reflective (less than 3 microns) channels that provides accuracy of +/- 3% or less in the earth albedo measurements for the scene of 100% albedo.

ABIPORD481 3.2.5.4.1-2 The ABI **shall** have an on-board calibration capability for the visible and near IR (less than 3 microns) channels that provides RMS repeatability of 0.2% or less. This requirement is met when no fewer than N independent calibrations are performed as closely as possible together in time and the RMS variation in each calibration coefficient is less than the specified level. N is the number of calibrations required to state at the 90% confidence level that the requirement has been met.

ABIPORD482 3.2.5.4.1-3 The ABI **shall** have an on-board calibration capability for the visible and near IR (less than 3 microns) channels that provides drift in absolute calibrated radiances of no more than 0.5% over the ABI lifetime. This requirement is met when the average change in calibrated scene radiance for scenes collected immediately before or after a calibration event do not change by more than 0.5% using the pre- and post-calibration coefficients for 99% of pixels in a full disk image.

3.2.5.5 Spatial Uniformity of Data

ABIPORD326 3.2.5.5-1 The ABI **shall** have less than 0.1% change in response in the calibrated pixel data over the field of regard while viewing a stable, uniform calibration source over expected geostationary environmental conditions and calibration frequency.

Channels with wavelengths less than 3 microns will be characterized as if viewing a 100% albedo calibration source. Channels with wavelengths greater than 3 microns will be characterized as if viewing a 300 K temperature calibration source.

3.2.5.6 Crosstalk

3.2.5.6.1 Channel-to-Channel

ABIPORD255 3.2.5.6.1-1 The ABI channel-to-channel (electrical, optical, spatial, spectral,) crosstalk **shall** be less than the derived NEDN. Channel-to-channel crosstalk is defined as the change in any channel output when one channel's illumination is changed from 0.1 N_{max} to a radiance of N_{max} while all other channels remain illuminated at a radiance level less than 0.1 N_{max} (ABIPORD149).

3.2.5.6.2 Within Channel

ABIPORD257 3.2.5.6.2-1 Non-adjacent pixel to pixel within channel cross talk, not including diffraction, **shall** be less than the derived NEDN. Within channel crosstalk is defined as the change in any non-adjacent pixel when one pixel's radiance is changed from 0.1 N_{max} to a radiance of N_{max} (ABIPORD149) while all other pixels in the same band remain illuminated at a radiance level less than 0.1 N_{max}.

3.2.5.7 Blooming

ABIPORD259 3.2.5.7-1 In all directions from the edge of a 500 by 500 microradian bright target at twice N_{max} (ABIPORD149), all detector outputs in channels with center wavelengths less than 2.0 microns **shall** recover to normal operation within 600 microradians.

ABIPORD260 3.2.5.7-2 In all directions from the edge of a 50 by 50 microradian bright target at twice maximum scene radiance, all detector outputs in channels with center wavelengths of 3.9 microns and 2.26 microns **shall** recover to normal operation within 500 microradians.

3.2.5.8 Quantization Step Size

ABIPORD263	3.2.5.8-1	The quantizing step size for all detector samples **shall** be less than 0.5 the derived NEDN

3.2.5.9 Electronic In-Flight Calibration

ABIPORD267	3.2.5.9-1	A system for calibrating and checking the linearity of the electronics and analog-to-digital converters **shall** be incorporated.
ABIPORD268	3.2.5.9-2	The calibration signal input non-linearity **shall** be such that all points within the dynamic range vary from a linear best fit by no more than 0.1% of N_{max} in ABIPORD149.
ABIPORD269	3.2.5.9-3	The calibration signal input dynamic range **shall** be greater than the dynamic range specified in ABIPORD149.
ABIPORD270	3.2.5.9-4	The calibration signal of requirement ABIPORD267 **shall** be inserted as close to the detector output signal as practicable in the electronics chain.

3.2.5.10 Polarization of Channel Less Than 3 Microns

3.2.5.10.1 Polarization Control

ABIPORD274	3.2.5.10.1-1	ABI channels with wavelengths less than 2 microns **shall** have less than 4% polarization sensitivity to the incoming light at all Earth-viewing angles.
ABIPORD275	3.2.5.10.1-2	The difference in polarization sensitivity to polarization between channels with wavelengths less than 2 microns **shall** be less than 2% at all Earth-viewing angles.

3.2.6 System Linearity

ABIPORD282	3.2.6-1	The ABI **shall** have linear radiometric response, before calibration, such that all points within the dynamic range vary from a linear best fit by no more than 1% of N_{max} in ABIPORD149 except for the 3.9 micron channel.
ABIPORD283	3.2.6-2	For the 3.9 micron channel, the ABI **shall** have linear radiometric response, before calibration, such that all points within the dynamic range vary from the linear best fit by no more than 1% at 375K except for the range between 375K and 400K.

3.2.7 Data Compression

ABIPORD483	3.2.7-1	The ABI **shall** perform lossless data compression on all data.
	3.2.7-2	The ABI may perform lossy data compression on the 0.47, 0.64, 0.86, and 1.61 micron channels.

3.2.7.1 Lossless Data Compression

ABIPORD286	3.2.7.1-1	Lossless data compression **shall** be in accordance with <u>CCSDS 121.0-B-1.</u>

3.2.7.2 Compression of the 0.47, 0.64, 0.86 and 1.61 Micron Channels

ABIPORD288 3.2.7.2-1 If performed, lossy compression **shall** meet the requirements listed in the Lossy Compression Requirement Table.

Lossy Compression Requirement Table

Metric	Definition	Requirement
Peak SNR	$$PSNR = 20\log_{10}\left(\frac{N_{\max}}{\sqrt{\frac{1}{MN}\sum_{i=1}^{N}\sum_{j=1}^{M}(X_{i,j}-\overline{X}_{i,j})^2}}\right)$$ where $N_{\max}$ is the maximum scene radiance in ABIPORD149, $X_{i,j}$ is the orginal image, $\overline{X}_{i,j}$ is the reconstructed image, and MN are the image dimensions	PSNR >= 50 dB
Correlated noise	$M=0.5*(M_{hGBIM}+M_{vGBIM})$, where M_{hGBIM} and M_{vGBIM} are defined in [1]	$\frac{M_{RC}}{M_{ORIG}} < 1.1$ where M_{RC} is the metric for the reconstructed image, and M_{ORIG} is for the original image

[1] H.R. Wu, "A New Distortion Measure for Video Coding Blocking Artifacts," in Proceedings of the 1996 Intern Conference on Communication Technology, vol. 2, May 5-7, 1996, Beijing, China, pp. 658-661.

ABIPORD290 3.2.7.2-2 If lossy data compression is performed, the ABI **shall** be capable of switching between lossy and lossless compression on orbit although the average data rate requirement does not apply when the ABI is commanded to send lossless data.

ABIPORD291 3.2.7.2-3 Command activation of lossy compression capability **shall** be on a channel-by-channel basis.

ABIPORD293 3.2.7.2-4 Solar reflective calibration data and space look data **shall** always be lossless compressed or uncompressed.

3.3 Design Requirements

3.3.1 Reliability

ABIPORD301	3.3.1-1	The ABI **shall** have a Reliability (R) of at least 0.6 after 10 years of on-orbit operations, preceded by up to 5 years of ground storage and up to 5 years of on-orbit storage.
ABIPORD309	3.3.1-2	The ABI shall have a Mean Mission Duration (MMD) of 8.4 years for a design life of 10 years.
ABIPORD460	3.3.1-3	The ABI **shall** have redundancy to eliminate all credible single-point failures.
ABIPORD461	3.3.1-4	The ABI redundant components **shall** be selectable by external command only.
ABIPORD462	3.3.1-5	The ABI units of any Flight Model **shall** be interchangeable, without modification, with the equivalent units of any other ABI Flight Model.
ABIPORD493	3.3.1-6	The ABI **shall** withstand without damage the sudden removal of operational power.

3.3.2 Mechanical Requirements

ABIPORD332	3.3.2-1	Each ABI unit structure **shall** possess sufficient strength, rigidity and other characteristics required to survive the critical loading conditions that exist within the envelope of handling and mission requirements

3.3.2.1 Design Limit Loads

ABIPORD355	3.3.2.1-1	The structure **shall** be capable of withstanding all limit loads without loss of any required function. Limit loads are defined as all worst case load conditions including temperature effects from the environments expected during all phases of the structure's service life including manufacturing, ground handling, transportation, environmental testing, integration, pre-launch, launch and on-orbit operations and storage.

3.3.2.2 Nonlinear Loads

ABIPORD357	3.3.2.2-1	The ABI structures **shall** be capable of withstanding redistribution of internal and external loads resulting from nonlinear effects including deflections under load.

3.3.2.3 Yield Strength

ABIPORD359	3.3.2.3-1	The ABI structures **shall** be able to support yield loads without detrimental permanent deformation. Yield loads are limit loads multiplied by the appropriate protoflight yield factor of safety specified in NASA-STD-5001. For structural elements containing beryllium or beryllium alloys, the prototype yield factor of safety is 1.4.
ABIPORD360	3.3.2.3-2	While subjected to any operational load up to yield operational loads, the resulting deformation **shall** not interfere with the operation of the ABI flight units. Operational load is defined as the expected on-orbit loads while the ABI is

operating.

3.3.2.4 Ultimate Strength

ABIPORD362 3.3.2.4-1 The ABI structures **shall** be able to support ultimate loads without fracture or collapse for at least 3 seconds including ultimate deflections and ultimate deformations of the flight unit structures and their boundaries. However, when proof of strength is shown by dynamic tests simulating actual load conditions, the 3-second limit does not apply. Ultimate loads are limit loads multiplied by the appropriate protoflight ultimate factor of safety specified in NASA-STD-5001. For structural elements containing beryllium or beryllium alloys, the prototype ultimate factor of safety is 1.6.

3.3.2.5 Structural Stiffness

ABIPORD364 3.3.2.5-1 Stiffness of the ABI structures and their attachments **shall** be designed by consideration of their performance requirements and their handling, transportation and launch environments.

ABIPORD365 3.3.2.5-2 Special stowage provisions **shall** be used if required to prevent excessive dynamic amplification during handling, transportation and transient flight events.

3.3.2.6 Unit Stiffness

ABIPORD367 3.3.2.6-1 The fundamental resonant frequency of the ABI sensor unit **shall** be 50 Hz or greater when the ABI sensor unit is rigidly constrained at its spacecraft interface and the ABI sensor unit is in its launch configuration.

ABIPORD538 3.3.2.6-2 The fundamental resonant frequency of the ABI electronics units **shall** be 50 Hz or greater when the ABI electronics units are rigidly constrained at their spacecraft interfaces.

3.3.2.7 Material Properties

ABIPORD369 3.3.2.7-1 Material properties **shall** be based on sufficient tests of the material meeting approved specifications to establish design values on a statistical basis.

ABIPORD370 3.3.2.7-2 Design values **shall** account for the probability of structural failures and loss of any required function due to material variability.

3.3.2.8 Critical Members Design Values

ABIPORD374 3.3.2.8-1 For critical members, design values **shall** be selected to assure strength with a minimum of 99 percent probability and 95 percent confidence. Structural members are classified as critical when their failure would result in loss of structural integrity of the flight units.

3.3.2.9 Redundant Members Design Values

ABIPORD376 3.3.2.9-1 For redundant members, design values **shall** be selected to assure strength with a minimum of 90 percent probability and 95 percent confidence. Structural members are classified as redundant when their failure would result in the redistribution of applied loads to other structural members without loss of structural integrity.

3.3.2.10 Selective Design Values

ABIPORD378 3.3.2.10-1 As an exception to ABIPORD374 and ABIPORD376, greater design values may be used if a representative portion of the material used in the structural member is tested before use to determine that the actual strength properties of that particular structural member will equal or exceed those used in the design.

3.3.2.11 Structural Reliability

ABIPORD380 3.3.2.11-1 The strength, detailed design, and fabrication of the structure **shall** prevent any critical failure due to fatigue, corrosion, manufacturing defects and fracture throughout the life of the ABI resulting in the loss of any mission objective.

ABIPORD381 3.3.2.11-2 Accounting for the presence of stress concentrations and the growth of undetectable flaws, the ABI structures **shall** withstand loads equivalent to four complete service lifetimes.

ABIPORD382 3.3.2.11-3 While subjected to any flight operational load up to limit flight operational loads, the resulting deformation of the residual ABI structures **shall** not interfere with the operation of the ABI units.

ABIPORD383 3.3.2.11-4 After any load up to limit loads, the resulting permanent deformation of the residual instrument flight unit structures **shall** not interfere with the operation of the ABI units.

3.3.2.12 Mechanisms

3.3.2.12-1 Deployment, sensor, pointing, drive, separation mechanisms and other moving mechanical assemblies may be designed using MIL-A-83577B and NASA TP-1999-206988.

ABIPORD389 3.3.2.12-2 All ABI mechanisms **shall** meet performance requirements while operating in an earth gravity environment with any orientation of the gravity vector.

ABIPORD390 3.3.2.12-3 Moving mechanical assemblies **shall** have torque and force ratios per section 2.4.5.3 of GEV-SE using a NASA approved classification of each instrument mechanism.

ABIPORD391 3.3.2.12-4 For all operating points of the actuators, all rotational actuators **shall** have available a continuous maximum torque output greater than 7.0 milli-Newton meters.

ABIPORD392 3.3.2.12-5 For all operating points of the actuators, all linear actuators **shall** have available a continuous maximum force output greater than 0.28 N.

ABIPORD393 3.3.2.12-6 For ABI mechanisms using closed-loop control, gain and phase margins **shall** be greater than 12 dB, and greater than 40 degrees, respectively including the effects of the dynamic properties of any flexible structure.

ABIPORD394	3.3.2.12-7	All ABI mechanisms requiring restraint during launch **shall** be caged during launch without requiring power to maintain the caged condition.
ABIPORD395	3.3.2.12-8	All ABI mechanisms requiring restraint **shall** be released from a caged condition by command.
ABIPORD396	3.3.2.12-9	All ABI mechanisms requiring restraint **shall** be returned to a caged condition ready for launch by either command or by manual actuation of an accessible caging device.

3.3.2.13 Pressurized Units

ABIPORD400	3.3.2.13-1	ABI pressurized systems **shall** follow the requirements in accordance with EWR-127-1 and MIL-STD-1522A for the design of pressurized systems.
ABIPORD401	3.3.2.13-2	The ABI **shall** have no open fluid reservoirs when delivered to the spacecraft contractor.

3.3.2.14 Alignment Reference

ABIPORD502	3.3.2.14-1	The ABI sensor unit **shall** have a permanent flight worthy optical alignment reference composed of a minimum 2.54 cm alignment cube and a mounting surface datum.
ABIPORD503	3.3.2.14-2	The ABI **shall** have a flight worthy cover for the optical alignment cube.
ABIPORD504	3.3.2.14-3	The ABI sensor unit **shall** have fiduciary marks locating the X, Y, and Z axes of the unit.

3.3.3 Thermal Requirements

3.3.3.1 Temperature Limits

ABIPORD403	3.3.3.1-1	The ABI contractor **shall** establish Mission Allowable Temperatures (MAT) for the ABI with at least 5 K of analytical/test uncertainty. Thermal margin is defined as the temperature delta between MAT versus the bounding predictions plus analytical uncertainty.
ABIPORD404	3.3.3.1-2	The ABI **shall** maintain thermally independent units and their internal components within MAT limits during all flight operational conditions including bounding worst-case environments.

3.3.3.2 Non Operational Temperature

ABIPORD408	3.3.3.2-1	The Non-Operational Temperatures (NOT) range **shall** extend at least 20 K warmer than the hot MAT and at least 20 K colder than the cold MAT.
ABIPORD409	3.3.3.2-2	The cold NOT **shall** be 248 K or colder.

3.3.3.3 Thermal Control Hardware

ABIPORD411 3.3.3.3-1 There **shall** be two or more serial and independent controls for disabling any heater where any failed on condition would cause over-temperature conditions or exceed the instrument power budget.

ABIPORD412 3.3.3.3-2 The ABI heaters **shall** be sized to have 25% margin for worst case conditions.

ABIPORD414 3.3.3.3-3 The ABI survival heaters **shall** be thermostatically controlled.

3.3.3.4 Dectector Cooling Margin

ABIPORD330 3.3.3.4-1 The following operating thermal margins **shall** be maintained in dectector cooling margin:

50% up to and including the conceptual design phase,

45% up to and including Preliminary Design Review (PDR),

40% up to and including Critical Design Review (CDR), and

30% thereafter including test and launch.

The detector operating thermal margin is based on heat loads. Detector operating thermal margin is the excess system cooling capability divided by the heat load (including End of Life (EOL) dissipations, parasitics and external fluxes). For multistage cooling systems, the margins apply to all stages simultaneously.

3.3.4 Onboard Processors Requirements

3.3.4.1 Flight Load Non-Volatile Memory

ABIPORD418 3.3.4.1-1 The entire flight software image **shall** be contained in non-volatile memory at launch.

3.3.4.2 Commandable Reinitialization

ABIPORD420 3.3.4.2-1 The On-board Processor **shall** provide for reset by command.

3.3.4.3 Deterministic Power-on Configuration

ABIPORD424 3.3.4.3-1 The On-Board Processor **shall** initialize upon power-up into a predetermined configuration.

3.3.4.4 Fail-safe Recovery Mode

ABIPORD422 3.3.4.4-1 The Instrument **shall** provide a fail-safe recovery mode dependent on a minimal hardware configuration capable of accepting and processing a minimal command subset sufficient to load and dump memory.

3.3.5 Flight Software Requirements

3.3.5.1 Language and Methodology

ABIPORD427 3.3.5.1-1 All software developed for the ABI instrument **shall** be developed with ANSI/ISO standard languages and a widely-accepted, industry-standard, formal software design methodology. Minimal use of processor-specific assembly language is permitted for certain low-level programs such as interrupt service routines and device drivers with NASA approval.

3.3.5.2 Flight Software Upload

ABIPORD429 3.3.5.2-1 The flight software **shall** be reprogrammable on-orbit without computer restart.

ABIPORD430 3.3.5.2-2 The flight software **shall** be capable of being uploaded in Computer Software Units (CSUs) and usable immediately after completion of the modified unit upload.

ABIPORD431 3.3.5.2-3 Activation of the modified CSUs **shall** not require completion of an upload of the entire flight software image.

3.3.5.3 Flexibility and Ease of Software Modification

ABIPORD434 3.3.5.3-1 The ABI flight software **shall** be deterministic in terms of scheduling and prioritization of critical processing tasks to ensure their timely completion.

ABIPORD435 3.3.5.3-2 All software data that are modifiable and examinable by ground operators **shall** be organized into tables that can be referenced by table number so table data can be loaded and dumped by the ground without reference to memory address.

ABIPORD436 3.3.5.3-3 The definition of instrument commands within the ground database **shall** not be dependent on physical memory addresses within the flight software.

3.3.5.4 Version Identifiers

ABIPORD438 3.3.5.4-1 All software and firmware versions **shall** be implemented with an internal identifier (embedded in the executive program) that can be included in the instrument engineering data.

ABIPORD439 3.3.5.4-2 This software identifier **shall** be keyed to the configuration management process.

3.3.5.5 Flight Processor Resource Sizing

ABIPORD441 3.3.5.5-1 During development, flight processors providing computing resources for instrument subsystems **shall** be sized for worst case utilization not to exceed the capacity shown below (measured as a percentage of total available resource capacity):

Flight Processor Resource Utilization Limits

	S/W PDR	S/W CDR	S/W AR

RAM Memory	40%	50%	60%
ROM Memory	50%	60%	70%
CPU	40%	50%	60%

3.3.5.6 Software Event Logging

ABIPORD443 3.3.5.6-1 The flight software **shall** include time-tagged event logging in telemetry.

ABIPORD444 3.3.5.6-2 The event messages **shall** include all anomalous events, mode transitions, and system performance events.

ABIPORD445 3.3.5.6-3 All flight software components **shall** utilize a common format for event messages.

ABIPORD446 3.3.5.6-4 The flight software **shall** provide a means for command to enable and disable queuing of individual event messages.

ABIPORD447 3.3.5.6-5 The flight software **shall** buffer a minimum of 1000 event messages while the event messages are queued for telemetering to the ground.

ABIPORD448 3.3.5.6-6 The event message queue **shall** be configurable by command to either (a) discard the new events, or (b) overwrite oldest events when the queue is full.

ABIPORD449 3.3.5.6-7 The flight software **shall** maintain counters for:

a) the total number of event messages generated

b) the number of event messages discarded because of queue overflow

c) the number of event messages not queued due to being disabled

3.3.5.7 Warm Restart

ABIPORD451 3.3.5.7-1 The flight software **shall** provide a restart by command with preservation of the event message queue and memory tables.

3.3.5.8 Memory Tests

ABIPORD453 3.3.5.8-1 The flight software **shall** provide a mechanism to verify the contents of all memory areas.

3.3.5.9 Memory Dump

ABIPORD455 3.3.5.9-1 The flight software, and associated on-board computer hardware, **shall** provide the capability to dump any location and any size of on-board memory to the ground upon command.

ABIPORD456 3.3.5.9-2 The flight software memory dump capability **shall** not disturb normal operations and instrument data processing.

3.3.5.10 Telemetry

ABIPORD458 3.3.5.10-1 Telemetry points sampled by the instrument **shall** be controlled by an on-orbit modifiable table.

ABIPORD459 3.3.5.10-2 The sample rate of every instrument telemetry point **shall** be controlled by an on-orbit modifiable table.

3.3.6 Power Requirements

3.3.6.1

3.3.6.1 Power Regulators and Supplies

ABIPORD487 3.3.6.1-1 The ABI power regulators and supplies **shall** have a phase margin of greater than 35 degrees.

ABIPORD488 3.3.6.1-2 The ABI power regulators and supplies **shall** have a gain margin of greater than 20 dB.

3.3.6.2 Fuses

ABIPORD490 3.3.6.2-1 The ABI **shall** not contain fuses.

3.3.6.3 Test Connectors

ABIPORD506 3.3.6.3-1 The ABI **shall** have flight qualified covers for all test point connectors.

3.3.7 Magnetic Properties

ABIPORD492 3.3.7-1 The change in the magnetic field produced by the ABI sensor, electronics, or power supply modules **shall** be less than 30 nanoTesla peak-to-peak for any operating mode, up to a single low pass bandwidth of 1.0 Hz, in any axis when measured at a distance of 1 meter from any face of a module.

3.3.8 Spacecraft Level Ground Testing

ABIPORD495 3.3.8-1 The ABI **shall** accommodate operational testing in all modes and states for indefinite periods during Spacecraft level Thermal Vacuum in at least the following two orientations:

1) Spacecraft +Y axis aligned with the gravity vector and pointed down.
2) Spacecraft -X axis aligned with the gravity vector and pointed down.

3.3.9 Ground Support Equipment and Development Facilities

3.3.9.1 Electrical System Test Equipment

ABIPORD508 3.3.9.1-1 The Electrical System Test Equipment (ESTE) **shall** operate the ABI and ground support equipment during performance verification and calibration testing.

ABIPORD509	3.3.9.1-2	The ESTE **shall** simulate the spacecraft interface with power, clock pulses, command, and telemetry functions.
ABIPORD510	3.3.9.1-3	The ESTE **shall** include all test equipment necessary to operate and control the ABI in all phases of operation and test modes.
ABIPORD511	3.3.9.1-4	The ESTE **shall** generate and maintain command logs.
ABIPORD512	3.3.9.1-5	The ESTE **shall** limit check all health and safety data.
ABIPORD514	3.3.9.1-6	The ESTE **shall** capture and archive all raw ABI data.
ABIPORD515	3.3.9.1-7	The ESTE **shall** provide near-real time and off line data analysis of all ABI data necessary to determine the performance characteristics of the instrument.
ABIPORD516	3.3.9.1-8	The ESTE **shall** interface with the Spacecraft Ground Support Equipment at the Spacecraft Contractor's facility to extract ABI science and engineering data.
ABIPORD539	3.3.9.1-9	The ESTE **shall** prohibit hazardous or critical commands being sent to the ABI without operator verification.

3.3.9.2 Flight Software Development Environment

ABIPORD519	3.3.9.2-1	The Flight Software Development Environment (FSDE) **shall** consist of the hardware and software systems used for realtime, closed loop testing on flight like hardware to develop, test, validate, and demonstrate the flight software is ready for Government acceptance.
ABIPORD520	3.3.9.2-2	The FSDE **shall** support all lifecycle activities (development, test, and validation) simultaneously.
ABIPORD521	3.3.9.2-3	The FSDE **shall** contain all items (software, databases, compilers, debuggers, etc.) needed to prepare flight software for the target processor.
ABIPORD540	3.3.9.2-4	The FSDE **shall** contain engineering (hardware) models of necessary flight hardware as well as dynamic software models comprising the remainder of the instrument and the necessary on-orbit environment.

3.3.9.3 Shipping Container

ABIPORD527	3.3.9.3-1	The ABI shipping container **shall** be compatible with shipment by air or air-ride van.
ABIPORD528	3.3.9.3-2	The ABI shipping container **shall** be climate controlled and purgable.
ABIPORD529	3.3.9.3-3	The ABI shipping container **shall** have internal temperature, humidity, and pressure monitors with external indicators.
ABIPORD530	3.3.9.3-4	The ABI shipping container **shall** have shock recorders.
ABIPORD532	3.3.9.3-5	The ABI shipping container **shall** meet all contamination control requirements imposed on the ABI instrument units.

ABIPORD533	3.3.9.3-6	The ABI shipping container **shall** be painted white and stenciled to indicate NASA property, content, and structural certification.
ABIPORD541	3.3.9.3-7	ABI GSE shipping containers **shall** be compatible with shipment by air or air-ride van.
ABIPORD542	3.3.9.3-8	The ABI GSE shipping containers **shall** be painted white and stenciled to indicate NASA property, content, and structural certification.

3.3.9.4 ABI Emulator

ABIPORD544	3.3.9.4-1	The ABI emulator **shall** simulate all instrument modes and mode transitions.
ABIPORD546	3.3.9.4-2	The ABI emulator **shall** simulate predefined, scripted anomalies.
ABIPORD547	3.3.9.4-3	The ABI emulator **shall** communicate with a spacecraft emulator for instrument command, telemetry, and science packets using Space Wire.
ABIPORD548	3.3.9.4-4	The ABI emulator **shall** use commercial power.
ABIPORD549	3.3.9.4-5	The ABI emulator **shall** execute ABI flight code.
ABIPORD550	3.3.9.4-6	The ABI emulator **shall** accept simulation control commands from a standalone console.
ABIPORD559	3.3.9.4-7	The ABI emulator **shall** accept simulation control commands from the spacecraft emulator.
ABIPORD551	3.3.9.4-8	The ABI emulator **shall** generate housekeeping data reflective of commanded mode and scan pattern.
ABIPORD552	3.3.9.4-9	The ABI emulator **shall** accept real-time inputs to change simulated telemetry or modeling parameters.
ABIPORD553	3.3.9.4-10	The ABI emulator **shall** maintain a log of all instrument commands received indicating validity, command mnemonic, and raw bit pattern.
ABIPORD554	3.3.9.4-11	The ABI emulator **shall** maintain a log of all simulation directives received.

4 Acronyms

4.0-1	A/D	Analog-to-Digital
	ABI	Advanced Baseline Imager
	ABI-GS	ABI-Ground System
	ACS	Attitude Control System
	AR	Acceptance Review
	CDR	Critical Design Review
	CONUS	Continental United States (excluding Alaska and Hawaii)
	CSU	Computer Software Units

EOL	End of Life
ESD	Electro-Static Discharge
ESTE	Electrical System Test Equipment
FOR	Field of Regard
FSDE	Flight Software Development Environment
GIRD	General Interface Requirements Document
GOES	Geostationary Operational Environmental Satellite
GSE	Ground Support Equipment
INR	Image Navigation and Registration
IR	Infrared
K	Kelvin
kHz	Kilohertz
km	Kilometers
m	meters
MAT	Mission Allowable Temperature
Mbps	Mega-bits-per-second
MLI	Multi-Layer Insulation
MMD	Mean Mission Duration
MTF	Modulation Transfer Function
mW	Milliwatt
NASA	National Aeronautics and Space Administration
NEDN	Noise Equivalent Delta Radiance
NEDT	Noise Equivalent Delta Temperature
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NOL	Non-Operating Limits
NOT	Non-Operating Temperature
OAT	Outgassing Allowable Temperature
OT	Operating Temperature
PDR	Preliminary Design Review
PORD	Performance Operational Requirements Document
rad	Radian

RMS	Root Mean Square
SNR	Signal-to-Noise Ration
sr	Steradian
S/W	Software
TBR	To Be Reviewed
TBS	To Be Supplied
TDI	Time Delay and Integration
TM	Thermal Margin
Tmin	Minimum Scene Temperature
Tmax	Maximum Scene Temperature
UIID	Unique Instrument Interface Document
um	Micrometers (Microns)
urad	Microradian